# INDOOR AIR QUALITY ASSESSMENT

**Watertown Fire Department, Station 2**
**534 Mount Auburn Street**
**Watertown, Massachusetts**


Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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## Background/Introduction

At the request of the Watertown Fire Fighters Union, Local 1347, an indoor air quality assessment was done at the Watertown Fire Department (WFD), Station 2 at 534 Mount Auburn Street, Watertown, Massachusetts. This assessment was conducted by the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH), Bureau of Environmental Health Assessment (BEHA).

On December 23, 2004, a visit was made to Station 2 by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program to conduct an indoor air quality assessment. Mr. Holmes was accompanied during the assessment by Gerard Cody, Chief Environmental Health Officer for the Watertown Health Department.

The station is a two-story red brick building with a basement that was constructed in 1912. The ground floor contains the engine bays and storage areas for fire fighting equipment. The second floor contains a bunkhouse (for overnight staff), office space, kitchen and lounge. Windows are openable throughout the building. The front of the building has three garage doors that enclose each engine bay. A stairwell connects the engine bays to the second floor. A fire pole with access to the engine bay is located in the second floor hallway near berthing areas.

## Methods

Air tests for carbon dioxide, carbon monoxide (CO), temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor. Air tests for ultrafine particulates (UFPs) were taken with the TSI, P-Trak ™ Ultrafine Particle Counter Model 8525.

## Results

The station is staffed 24 hours a day, seven days a week and has an employee population of 24 (6 per shift). The station is visited by approximately 2-5 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results for general air quality parameters (e.g., carbon dioxide, temperature and relative humidity) appear in Table 1. A second set of test results for UFPs and CO were taken after operating emergency response vehicles after a simulated call. These results are listed in Table 2.

## Discussion

### Ventilation

It can be seen from the tables that carbon dioxide levels were below 800 parts per million (ppm) in all occupied areas surveyed, indicating adequate air exchange. However, it is important to note that elevated carbon dioxide levels were measured in the stairwell connecting the engine bay to the second floor. This suggests that air circulation is poor in this stairwell, which is described in more detail in the Vehicle Exhaust section of this report. The station does not have any means of mechanical ventilation in the general work/living areas but uses windows to introduce fresh air.

A vehicle exhaust ventilation system is installed in the engine bay to remove carbon monoxide and other products of combustion; the system is described in detail under the Vehicle Exhaust portion of this report.

Air conditioning is provided by air handling units (AHUs) located in the attic (Picture 1). The AHUs do not have the capability to introduce outside air but recirculate air *only*. AHUs are ducted to wall or ceiling mounted air diffusers (Picture 2). Ceiling and wall-mounted return vents (Picture 3) draw air back to the AHUs via ductwork. These systems were not operating during the assessment. Station personnel could not confirm that a preventive maintenance program was in place for air handling equipment.

The Massachusetts Building Code requires a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings in occupied areas were measured in a range of 70° F to 74° F, which were within the BEHA recommended comfort range. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control and airflow complaints were specifically reported in dorm room 5.

Relative humidity measurements ranged from 43 to 59 percent, which were within the BEHA recommended comfort guidelines. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

**Microbial/Moisture Concerns**

A number of areas had water-damaged ceiling tiles (Picture 4). Occupants reported that ceiling tiles became damaged as a result of condensation from air conditioning equipment during the cooling season. Water-damaged ceiling tiles can provide a source of mold and should be replaced after a moisture source or leak is discovered and repaired.

**Vehicle Exhaust**

Under normal conditions, several sources of environmental pollutants can be present in a firehouse. These sources of pollutants, which primarily stem from fire vehicle operation, may include:

- Vehicle exhaust, which contains carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids, which contain volatile organic compounds (VOCs);
- Water vapor from drying hose equipment;
- Rubber odors from new vehicle tires; and
- Fire residues on vehicles, hoses and fire-turnout gear.

Of particular importance is vehicle exhaust. The use of fossil fuel-powered equipment (e.g., propane heaters, diesel or gasoline-powered vehicles, acetylene welding) involves the process of combustion. The process of combustion produces airborne liquids, solids and gases (NFPA, 1997). Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, carbon monoxide and particulate matter can produce health effects upon exposure. In order to assess whether contaminants generated by diesel engines were migrating into occupied areas of the station, measurements for carbon monoxide and airborne particulates were taken and used to pinpoint the source/pathway of combustion products.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce acute (immediate) health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency (US EPA) has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide should not be present in a typical, indoor environment. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were measured in a range of 0-2 ppm. Carbon monoxide levels measured in the WFD measured 0-3 ppm (Table 2). The measurement of 3 ppm was taken in the kitchen, which had several gas-fired cooking appliances.

Using carbon monoxide measurements alone to detect sources of combustion pollutants has limitations. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. As discussed, combustion of fossil fuels can also produce particulate matter of a small diameter [10 micrometers (μm)]. For this reason, a device that can measure particles of a diameter of 10 µm or less was also used to identify pollutant pathways from vehicles into the occupied areas.

The US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS established exposure limits for particulate matter with a diameter of 10 µm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter (µg/m3) in a 24-hour average.

BEHA staff conducted air monitoring for airborne particulate with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525, which counts the number of particles that are suspended in a cubic centimeter ($cm^3$) of air. This type of air monitoring is useful for tracking and identifying the source of airborne pollutants by counting the actual number of airborne particles. The source of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or whether particles are penetrating through spaces in doors or walls, it cannot be used to quantify whether NAAQS PM10 standards have been exceeded. The primary purpose of these tests is identifying and reducing/preventing pollutant pathways.

Air monitoring for ultrafine particles (UFPs) was conducted around doors that provide access to the engine bay. Monitoring was also conducted in several areas on the first and second floor of the station. Measurements were taken prior to and after diesel engine operation. The highest reading for UFPs was taken in the engine bay, after diesel engine operation. These elevated measurements would be expected during the normal operation of motor vehicles in an indoor environment.

As mentioned previously, the station is equipped with a mechanical exhaust system to remove exhaust from the engine bay during vehicle idling. The local exhaust system consists of series of exhaust vents that feed into a main duct connected to a large exhaust motor located at the rear of the engine bay (Pictures 5 and 6). Make up air is provided through louvered vents that on exterior walls of the engine bay (Picture 7). The activation of this system appears to be dependent on a combination of chemical sensors (carbon monoxide and nitrogen dioxide) (Pictures 8 and 9). Once a pre-set reading is exceeded, the local exhaust system is activated to introduce fresh air and remove exhaust emissions.

Therefore, no mechanical exhaust ventilation is provided until the set-point is exceeded to activate the system. As discussed, BEHA staff had the WFD personnel simulate a call, in which all fire-fighting and emergency support vehicles were started, removed from and returned to the engine bay. Neither during this activity nor after did the local exhaust system activate to remove vehicle emissions. In addition, WFD personnel could not identify what the set-points for the chemical sensors were nor the last time they were serviced and/or calibrated.

A number of pathways for vehicle exhaust and other pollutants to move from the engine bays into occupied areas on both the first and second floors were identified (Figure 1). The main pathway for vehicle exhaust emissions is the stairwell off the engine bay, which lacks a door at its base (Picture 10). Without an air-tight door vehicle exhaust odors, carbon dioxide and UFPs were migrating into and pooling within the stairwell (Tables 1 and 2). The door at the top of the stairwell leading to the office areas and living quarters had spaces beneath the door (light could be seen penetrating through this space). The second floor windows were open during operation of fire fighting vehicles, which can lead to the increased draw of exhaust emissions into the room (called entrainment) through the open windows under certain wind and weather conditions.

Another possible pathway for exhaust emissions is through utility holes. The ceiling/walls of the engine bays are penetrated by holes for utilities. These holes can present potential pathways into occupied areas if they are not air-tight. Each of these conditions presents a pathway for air to move from the engine bays to occupied areas of the station. In order to understand how engine bay pollutants may be impacting the second floor and adjacent areas, the following concepts concerning heated air and creation of air movement must be considered:

- Heated air will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As heated air rises, negative pressure is created, which draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- The operation of HVAC systems (including rest room exhaust vents) can create negative air pressure, which can draw air and pollutants from the engine bays.

Each of these concepts has influence on the movement of odors to the second floor and dispatch office. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer engine bays can place the garage under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into the second floor, these pollutant pathways should be sealed.

### Other Concerns

Several conditions that can potentially affect indoor air quality were also identified during the assessment. WFD staff could not identify the date of the last filter change in AC units. BEHA staff examined AHUs in the attic and found the filter access panel for one of the units was not installed (Picture 11). If not installed, the lack of the filter access panel will render the AHU casing non-air-tight and will draw air from the attic space into the unit. As air bypasses filters, the opportunity exists for airborne dirt, dust and particulates to be distributed to occupied areas via the HVAC system. Aerosolized dust, particulates and fiberglass can provide a source of eye, skin and respiratory irritation to certain individuals. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving, and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation.

In addition, the type of filters installed in the units provides minimal respirable dust filtration (Picture 13). In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed in AHUs. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the univent through increased resistance (called pressure drop). Prior to any increase in filtration, AHUs should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

## Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Manually activate local exhaust system upon exiting and returning to engine bays.
2. Contact the manufacture and/or installer regarding the operation and calibration of the of the chemical sensor/local exhaust ventilation system. Maintain and calibrate it in accordance with the manufacturer's instructions.
3. Install doors to stairwell leading off the engine bay. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
4. If possible, install an automatic control to activate the engine bay exhaust system as engine bay doors open.
5. Ensure all utility holes are properly sealed in both the engine bay and their terminus to eliminate pollutant paths of migration.
6. Work with town officials to develop a preventative maintenance program for all HVAC equipment department wide.
7. Change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed. Consider increasing the dust-spot efficiency of HVAC filters. Prior to any increase of filtration, each piece of air handling equipment should be

evaluated by a ventilation engineer as to whether it can maintain function with more efficient filters.

8. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
9. Replace water-damaged ceiling tiles. Examine the area above and behind these areas for microbial growth. Disinfect areas of water leaks with an appropriate antimicrobial.
10. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

## References

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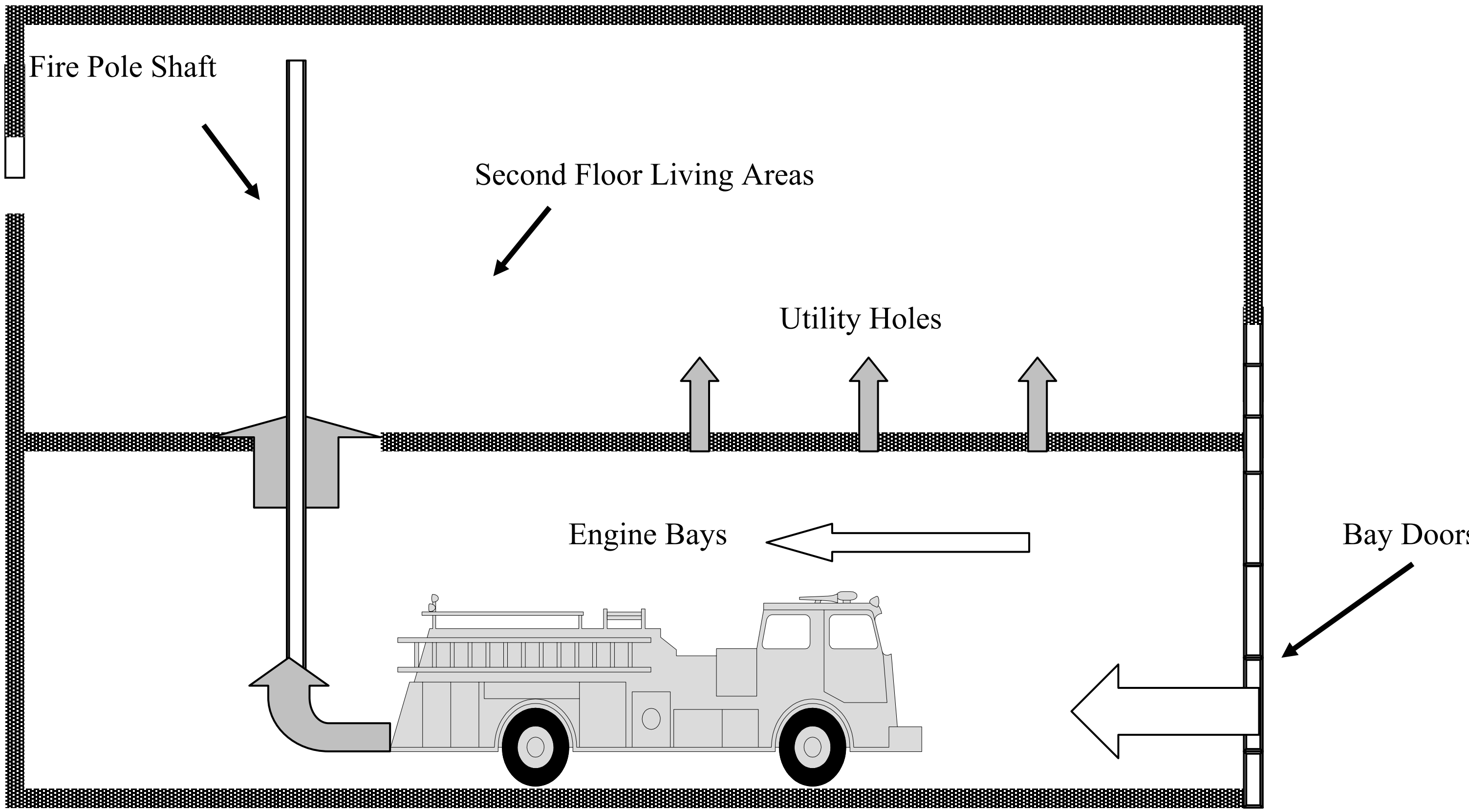
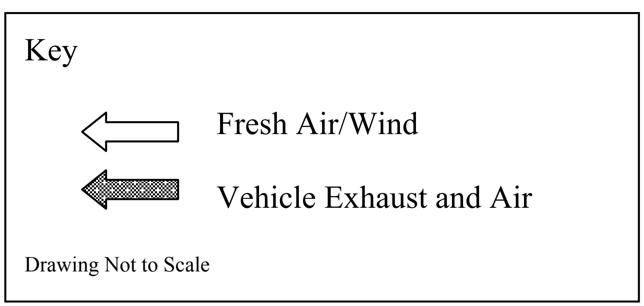
**Figure 1** **Potential Pathways of Air and Pollutant Movement from Engine Bays into Occupied Areas***




* Note exhaust is minimized via the vehicle exhaust ventilation system



**Picture 1**

**One of Two Air Handling Units in the Attic**

**Picture 2**


**Ceiling-Mounted Supply Vent for AC System**

**Picture 3**


**Ceiling-Mounted Return Vent**

**Picture 4**


**Water Damaged Ceiling Tiles**

**Picture 5**

**Engine Bay Exhaust Vents Feeding into the Main Exhaust Duct**

**Picture 6**

**Exhaust Motor for Engine Bay Exhaust System on Exterior of Building**

**Picture 7**

**Louvered Make-Up Air Vents for Engine Bay Exhaust System**

**Picture 8**


**Wall-Mounted Carbon Monoxide Sensor in Engine Bay**

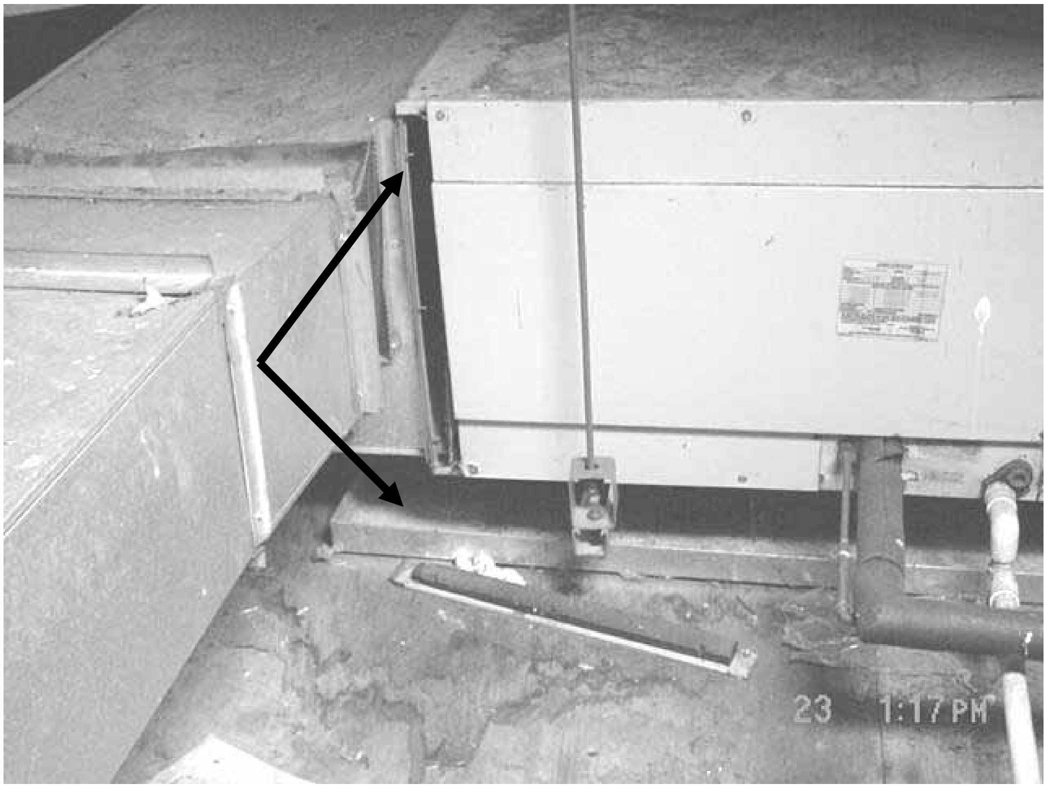
**Picture 9**


**Wall-Mounted Carbon Monoxide/Nitrogen Dioxide Alarm Panel in Engine Bay**

**Picture 10**

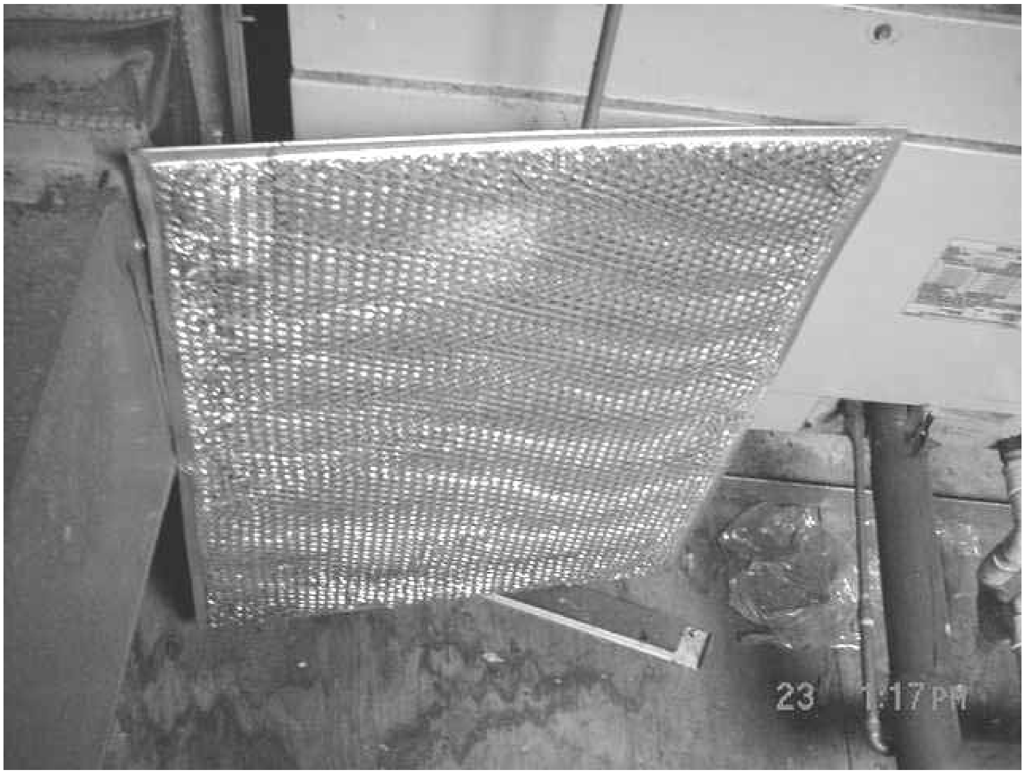

**View of Engine Bay/Stairwell Entrance from Directly Behind Engine, Note Lack of Door**

**Picture 11**




**AHU in Attic, Note Filter Access Panel on Floor**

**Picture 12**




**Wire Mesh Filter Installed in Attic AHUs**

**TABLE 1**

## Indoor Air Test Results – Fire Dept. Station 2, Mt Vernon St., Watertown, MA – December 23, 2004

| Location | Carbon Dioxide (*ppm) | Temp (°F) | Relative Humidity (%) | Occupants in Room | Windows Openable | Ventilation | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Supply | Exhaust | |
| Background | 357 | 54 | 65 | | | | | Weather conditions: Cloudy, drizzle, SE winds 10-15 mph, moderate to heavy traffic |
| Recreation Room | 545 | 74 | 48 | 0 | Y | N | N | |
| Kitchen | 571 | 74 | 49 | 5 | Y | N | N | Gas stove, window open |
| Office | 549 | 74 | 46 | 2 | Y | N | N | 5 CT |
| Dorm Room 1 | 463 | 73 | 44 | 0 | Y | N | N | |
| Dorm Room 2 | 496 | 73 | 45 | 0 | Y | N | N | 1 CT |
| Fire Pole Upstairs Hallway | 474 | 73 | 45 | 0 | Y | N | N | |
| Men's Rest Room/Shower | 570 | 73 | 46 | 0 | N | N | Y | Exhaust vents not operating |
| Dorm Room 3 | 497 | 73 | 44 | 0 | Y | N | N | 2 CT |
| Dorm Room 4 | 436 | 72 | 44 | 0 | Y | N | N | 3 CT, window open |

*** ppm = parts per million parts of air**
**CT = Water damaged Ceiling Tiles**

**Comfort Guidelines**

| | |
|---|---|
| Carbon Dioxide - | < 600 ppm = preferred |
| | 600 - 800 ppm = acceptable |
| | > 800 ppm = indicative of ventilation problems |
| Temperature - | 70 - 78 °F |
| Relative Humidity - | 40 - 60% |

## TABLE 1

### Indoor Air Test Results – Fire Dept. Station 2, Mt Vernon St., Watertown, MA – December 23, 2004

| Location | Carbon Dioxide (*ppm) | Temp (°F) | Relative Humidity (%) | Occupants in Room | Windows Openable | Ventilation | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Supply | Exhaust | |
| Women's Restroom/ Shower | 435 | 72 | 43 | 0 | Y | N | Y | Exhaust vents not operating |
| Dorm 5 | 411 | 72 | 45 | 0 | Y | N | N | Window open, temperature control complaints-AC too strong |
| Dorm 6 | 392 | 71 | 46 | 0 | Y | N | N | Window open |
| Stairwell | 855 | 70 | 45 | | | | | No door at bottom of stairwell/engine bay, |
| Engine Bay | 512 | 71 | 59 | 0 | N | Y | Y | 3 Bay Garage Doors, local exhaust system-chemical sensor/manually activated |

*** ppm = parts per million parts of air**
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**TABLE 2**

## Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
## Fire Dept. Station 2, Mount Vernon St., Watertown, MA – December 23, 2004

| Location | Carbon Monoxide (**ppm) Before | Carbon Monoxide (**ppm) After | Ultrafine Particulates 1000p/cc$^3$ Before | Ultrafine Particulates 1000p/cc$^3$ After | Comments |
|---|---|---|---|---|---|
| Background | 0-2 | 0-2 | 7.2-12.7 | 8.7-16.9 | |
| Stairwell | 1 | 1 | 27.4 | 58 | |
| Engine Bay | 1-2 | 1-2 | 26.7 | 120 | |
| Recreation Room | ND | ND | 27.6 | 14.3 | |
| Kitchen | 0-1 | ND | 21 | 16.8 | Window Open |
| Office | ND | ND | 37.8 | 16.8 | |
| Dorm Room 1 | ND | ND | 29.5 | 12.7 | Window Open |
| Dorm Room 2 | ND | ND | 26.2 | 16.6 | Window Open |
| Fire Pole 2nd Floor Hallway | ND | ND | 24.4 | 37.7 | |
| Dorm Room 3 | ND | ND | 19.2 | 13.3 | |
| Dorm Room 4 | ND | ND | 20 | 13.3 | |
| Dorm Room 5 | ND | ND | 15.4 | 20.8 | |

**** ppm = parts per million parts of air**
*** testing before and after starting diesel engines and response vehicles for simulated call**

**TABLE 2**

## Indoor Air Test Results* for Ultrafine Particulates and Carbon Monoxide
## Fire Dept. Station 2, Mount Vernon St., Watertown, MA – December 23, 2004

| Location | Carbon Monoxide (**ppm) Before | Carbon Monoxide (**ppm) After | Ultrafine Particulates 1000p/cc$^3$ Before | Ultrafine Particulates 1000p/cc$^3$ After | Comments |
|---|---|---|---|---|---|
| Dorm Room 6 | ND | ND | 16.6 | 20.4 | Window Open-Garbage Truck-Idling |

** ppm = parts per million parts of air
* testing before and after starting diesel engines and response vehicles for simulated call